Experimental Validation of a Fracture Model for Pearlitic Steel Bars Based on the Cohesive Zone Model

F. Suárez[1*], J. C. Gálvez[1], J. M. Atienza[2], D. A. Cendón[2], M. Elices[2]

[1] Departamento de Ingeniería Civil-Construcción, Universidad Politécnica de Madrid, E.T.S.I. Caminos, Canales y Puertos, C/Profesor Aranguren s/n 28040 – Madrid, Spain, fsuarez@caminos.upm.es
[2] Departamento de Ciencia de Materiales, Universidad Politécnica de Madrid, E.T.S.I. Caminos, Canales y Puertos, C/Profesor Aranguren s/n 28040 – Madrid, Spain

Steel is, together with concrete, the most widely used material in civil engineering works. Not only its high strength, but also its ductility is of special interest, since it allows for more energy to be stored before failure. A better understanding of the material behaviour before failure may lead to better structural safety strategies.

The characterisation of metallic materials is usually carried out as described by ISO 6892-1 standard, which defines the tensile testing method for metallic materials. When the maximum load point is reached, necking process begins. This makes difficult to study the behaviour of the material from that moment until failure.

On another point, metallic cylindrical specimens tested under tension usually show a cup-cone surface after failure and the failure mechanism is usually explained with the theory of nucleation, growth and coalescence of microvoids. Based on this theory, many numerical models have been developed, with a special mention to the Gurson-type models [1]. These models simulate mathematically the physical growth of microvoids, leading to a progressive development of the internal damage that takes place during a tensile test. In these models, the damage starts to develop in very early stages of the test.

Nevertheless, cylindrical specimens made of pearlitic steel rods used for manufacturing prestressing steel wires do not show a cup-cone fracture surface. These specimens show a flat fracture surface with a dark region in the centre of it. Experimental results obtained by the authors [2, 3] suggest that, in the case of this material, failure takes place as a result of a ductile-brittle transition process. Therefore, in this type of materials, a quasi-brittle fracture is developed as a consequence of a decohesion process, with the dark region acting as a circular crack perpendicular to the loading direction.

In the authors' opinion, using a cohesive model as a failure criterion is interesting in this case, since a cohesive model only requires two parameters to be defined, with the fracture energy being one of them, which can be obtained experimentally. In addition to this, given that it is known that the stress triaxiality has a strong influence on the fracture of ductile materials, a cohesive model whose parameters are affected by the value of the stress triaxiality can be considered.

This work presents the experimental validation of a fracture model for steel specimens in a tensile test, based on a cohesive behaviour and taking into account the effect of stress triaxiality. Experimental tests have been carried out on cylindrical specimens of three different diameters: 3, 6 and 9mm. These tests have been reproduced numerically using the aforementioned cohesive element. Results from the numerical simulations have been compared with the experimental results, showing good agreement with them.

References

[1] V. Tvergaard, A. Needleman, Analysis of the cup-cone fracture in a round tensile bar, Acta Metall Mater 32 (1984) 157–169.

[2] F. Suárez, J. C. Gálvez, D. A. Cendón, J. M. Atienza, M. Elices, Análisis de la deformación de rotura en el ensayo de tracción en probetas cilíndricas de acero perlítico, in: Proc., Anales de Mecánica de la Fractura, Gijón, 28, Vol. I, 205–210, 2011.

[3] F. Suárez, D. A. Cendón, J. C. Gálvez, J. M. Atienza, M. Elices, A fracture model for pearlitic steel bars using a cohesive model, in: Proc., ECCOMAS 2012, Viena, 2012.